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Technical Report: NAVTRADEVCEN 836-2

TRAINING FOR PARTIAL-PANEL CONTROL SKILLS

George E. Briggs

Laboratory of Aviation Psychology
The Ohio State University
Columbus, Ohio

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ABSTRACT

Several schedules of training were compared for the acquisition of vehicular control skill in a two-dimensional tracking task. The final transfer task utilized only two information displays (system error in both task dimensions). The training tasks utilized a five-display and a three-display-panel condition, and the several training schedules emphasized practice on one or the other of these panels prior to final transfer. None of the schedules resulted in performance on the final, two-display task which was superior to performance attained by a control group of subjects who trained only on the two-display condition throughout the training period. It appears that these negative results were due, in part, to the relative simplicity of the basic tracking task.

FOREWORD

Purpose

What features should a training program possess in developing perceptual-motor skills? To provide information on this question, the U. S. Naval Training Device Center has initiated a series of studies. Previous research, as reported in Technical Report: NAVTRADEVCEN 836-1, explored the use of display aiding and augmented feedback as training variables. It was found that an intermediate amount of training on completely- and partially-aided displays provided the best transfer. It was shown that two forms of supplemental feedback (augmented and summary) have a significantly beneficial effect on skill acquisition.

One implication generated from that study was that the student needed more display information during the early stages of learning than in the later stages. Consequently, this present study tests the following hypothesis: a training schedule which progressively reduces the number of displays used for controlling a vehicle will provide better training than will a schedule that trains from the start on a reduced number of displays.

Results

Groups of students who began learning a vehicular skill with five informational displays, then three displays, and finally two displays were compared on a two-display task with students who learned only with two displays. None of the groups who learned under progressively fewer informational displays performed better than the control group trained only on two-display conditions throughout the training period. The results may have been due in part to the two-display task being too easy.

Implications

Laboratory verification of these results with more difficult transfer tasks and longer training periods is necessary before their application can be recommended.

Clayton K. Bishop

Clayton K. Bishop, Ph.D.
Head, Crew Training Systems Branch

James J. Regan

James J. Regan, Ph.D.
Head, Systems Psychology Division

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BRIEF OF THE STUDY

Introduction

This study is related to two earlier experiments in this series (Briggs, 1961) on the scheduling of changes in displayed information during the acquisition of vehicular control skills. In that earlier report, an analysis of skill was provided which indicated that the human operator progresses, with training, from the novice stage during which he responds almost exclusively to system error amplitudes, through a phase when his control responses are based on both the amplitude of system error and the rate at which error is changing, until eventually he attains high skill by utilizing not only error amplitude and error rate information but also determines his controlling responses in part by reference to the acceleration characteristics of system error. Previous laboratory research supports this analysis (Garvey & Mitnick, 1957; Fuchs, 1962).

One implication from this analysis is that the human operator needs more displayed information on the derivatives of system error early in training than he does at a later stage. This implication is based on the following reasoning: a display of instantaneous system error amplitude contains information on error rate and acceleration which the operator himself may estimate by observing the display indications over time (the rates and accelerations of cursor movement). Thus, it is possible to maintain a reasonably accurate heading in an aircraft by reference only to the gyro compass, since the pilot can observe not only the extent (amplitude) of heading error at any time, but also he can note the rate at which the compass is rotating and the extent to which his flight path is accelerating away from the desired heading. However, it is obvious that only the highly skilled pilot can operate effectively under such partial-panel conditions, and in order to hold a particular course without undue oscillations around the desired heading, the less skilled operator requires the bank and turn indicator plus the artificial horizon (displayed derivative information).

Purpose of the Research

This study represents a test of the hypothesis that progressive reductions in displayed derivative information during training will facilitate the acquisition of controlling accuracy on a display showing only system error amplitudes compared to training under that latter display condition without prior experience on derivative displays. Therefore, the study is analogous to a test of two pilot training programs, one of which provides the entire instrument panel during the early stages followed by successive removals of instruments until only the compass and altimeter remain, the other program providing only the compass and the altimeter from the beginning.

In theory, the progressive-reduction schedule should provide for performance on the partial-panel condition which is superior to that of operators trained only on the partial panel when such comparison is made after equal amounts of training.

Design of the Experiment

There were one control and four experimental groups involved. The subjects (Ss) were undergraduate males at Ohio State University, and each S participated for nine 30-min. sessions. There was a total of 85 70-sec. trials or 90+ min. of tracking experience per S. Figure 1 of the Appendix provides a computer diagram of the tracking task. That information may be summarized by noting that all Ss experienced a two-dimensional task analogous in dynamics to heading and altitude control in an aircraft, i.e., S controlled heading through one exponential and two integral lags and he attempted to hold altitude through one exponential and one integral lag. Unlike the aircraft, however, there was no cross-coupling between the two dimensions.

The control group, Group 1, tracked via only two displays, one showing system error in heading (heading error) while the other indicated altitude error. The four experimental groups began their training with five information displays: heading error, heading rate error, and heading acceleration error, plus altitude error and altitude rate error. Following this condition, the experimental groups experienced a three-display condition: heading error, heading rate error, and altitude error; and finally, these groups transferred to the two-display condition experienced throughout by the control group: heading error and altitude error. The absolute and relative amounts of training on the five- and the three-display conditions defined the experimental groups and this information is summarized in Table 1.

From Table 1 it may be noted that Groups 2 and 3 received only three sessions of training, while Groups 4 and 5 experienced a total of seven training periods prior to final transfer. Further, within these pairs of groups, one training schedule emphasized the complete, five-display condition (Groups 3 and 5), while another emphasized experience with the three-display panel (Groups 2 and 4). Thus, the experiment was concerned not only with the efficiency of training with complete and near-complete panel information for

Table 1

Number of Thirty-Minute Sessions Devoted to Tracking Via Five, Three, and Two Information-Display Conditions

Group	Training Condition: Five Displays	Training Condition: Three Displays	Transfer Condition: Two Displays
1	0	0	9
2	1	2	6
3	2	1	6
4	3	4	2
5	4	3	2

partial-panel control, but also with the effects of absolute amount of training (Groups 2 and 3 vs. Groups 4 and 5), and with training emphasis (Groups 2 and 4 vs. Groups 3 and 5) in terms of complete (five-display) vs. near-complete (three-display) display conditions.

Results and Discussion

The results of primary interest are a comparison of control and experimental groups at the time of transfer to the partial-panel or two-display condition. For Groups 2 and 3 these are the data of Session 4, and for Groups 4 and 5 the data of Session 8 provide the necessary information. In order to make these comparisons, the group averages of tracking error (for heading and altitude error combined) were inserted in the equation

$$\frac{C_1 - E_T}{C_1 - C_T} \times 100$$

This equation provides a percent transfer index where C_1 is the initial performance of Group 1 (the control group) in Session 1, E_T is the transfer performance level of an experimental group, and C_T is the performance level of Group 1 in the same session. It should be noted that to the extent this index is less than 100%, to that extent the control group was superior to the experimental group, and vice versa for indices greater than 100%. Table 2 provides the transfer indices for each of the four experimental groups.

From visual observation it appears that none of the experimental groups performed as well as the control group in transfer performance (all groups obtained transfer indices less than 100%). Thus, the experimental hypothesis described on page 1 was not confirmed by the data, and it may be concluded that if one trains for partial-panel control, he gains little or nothing by practicing control via a full panel or near-complete panel of derivative display information. In fact, the transfer indices of Table 2 indicate that training on complete and on near-complete panels may be relatively detrimental to performance on the partial-panel condition.

Comparing the four experimental groups, it appears that percent transfer differed as a function of amount of training (the average of Groups

Table 2

Percent Transfer for the Four Experimental Groups
(Group number appears in parenthesis)

Training Emphasis	Amount of Training Three Sessions	Seven Sessions
Three Displays	85.8 (2)	85.5 (4)
Five Displays	84.2 (3)	91.9 (5)

2 and 3 vs. the average of Groups 4 and 5) and that there was a numerical superiority for those groups trained with emphasis on the five-display condition (the average of Groups 3 and 5 vs. the average of Groups 2 and 4). However, these comparisons lack statistical significance, and so it is concluded that neither amount of training nor training emphasis differentially influenced the relative performance of S on the final transfer task.

Negative results demand some attempt at explanation. In the present case it is suggested that the lack of cross-coupling between the two tracking dimensions may be responsible, in part, for the failure of the two experimental variables (amount of training and training emphasis) to differentiate among group performance levels upon transfer, i.e., the task was too simple. Further, the failure of any experimental group to exceed the performance of the control group may well be a result of the experimental group Ss' learning no more of the fundamental tracking task requirements than did the control Ss, despite the fact that the experimental groups were provided with more detailed information on the subtle aspects of system control—rate and acceleration information.

The implication of these results, then, is that a "sink-or-swim" schedule of training will be superior to a systematic reduction in system information when one is training specifically for controlling skill with minimal system error information. However, this implication should hold only for those multidimensional tasks wherein independent control of the several dimensions is possible; and intercoupled control between dimensions, which would result in a more complex task, may very well show that one of the several training schedules utilized herein would be superior to the sink-or-swim training procedure.

SECTION II
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SECTION III
TECHNICAL APPENDIX

Apparatus

An attempt was made to develop a tracking task similar in dynamics to that found in the control of heading and altitude in an aircraft. However, it was decided to simplify the task dynamics considerably due to a limitation on the number of operational amplifiers available for such simulation. The device as developed did not, for example, include a cross-coupling between the two dimensions as would be present in the operational system, i.e., there was no loss of lift with bank attitudes in the simulator.

A schematic of the tracking system is provided in Figure 1. An EASE analog computer was utilized to provide the dynamics of the task which, as indicated in Figure 1, consisted of two integral lags (Amplifiers 2 and 3),

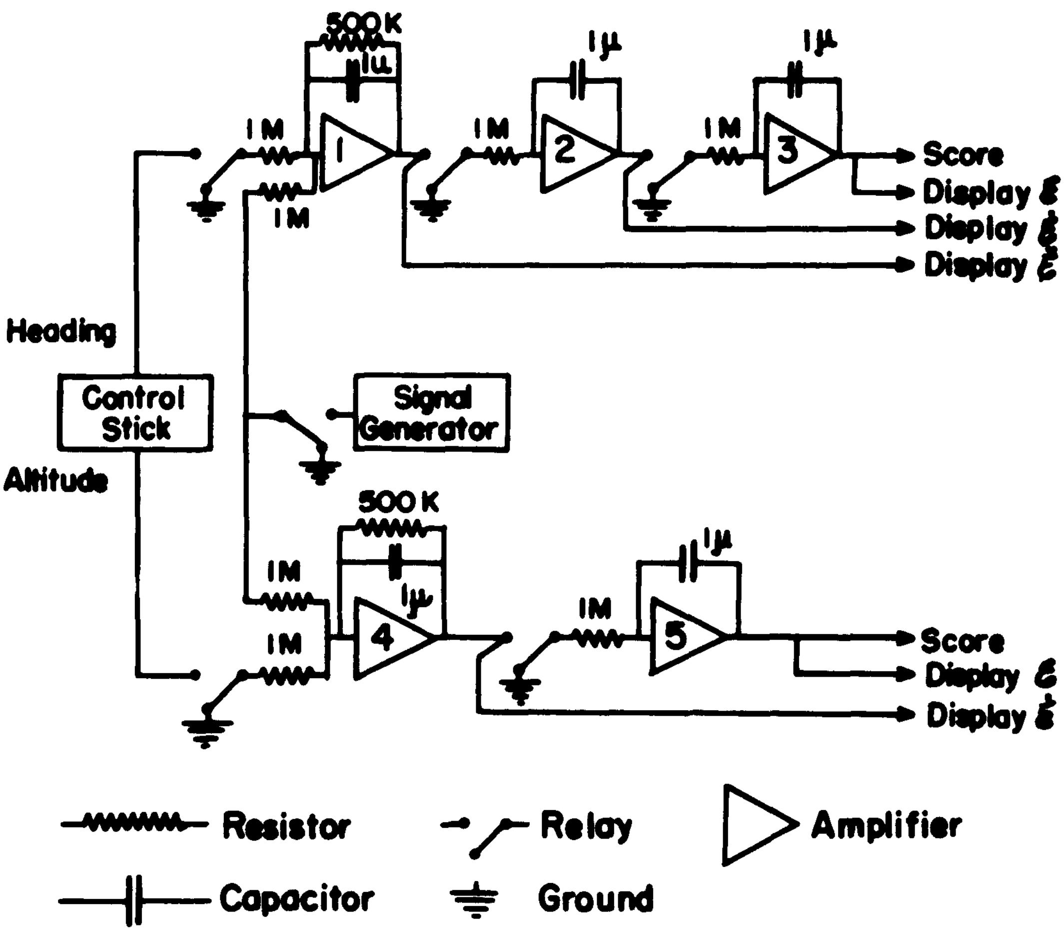

Figure 1. Tracking Task Dynamics for Heading and Altitude Control.

plus an exponential lag (Amplifier 1) for heading control and a single integral lag (Amplifier 5) plus an exponential lag (Amplifier 4) for altitude control. The system input, a 5-cpm sinusoid, was inserted into both dimensions of the system, as shown. Thus, since the output of Amplifier 3 was displayed to S as system heading error, ε, the output of Amplifier 2 is heading error rate, $\dot{\varepsilon}$, and the output of Amplifier 1 is heading error acceleration, $\ddot{\varepsilon}$. These latter two signals were displayed during the five-display condition for Groups 2-5; heading error and heading error rate were displayed during the three-display condition; and heading error display provided the only information on this dimension for the control group throughout and for the four experimental groups during the final transfer sessions. Altitude error (the output of Amplifier 5), ε, was displayed to all Ss under all conditions, but altitude error rate (the output of Amplifier 4), $\dot{\varepsilon}$, was viewed only by the experimental groups and only during the five-display condition.

Subjects and Procedure

A total of 102 undergraduate males volunteered for service in the study, and they were assigned to groups on a chance basis with the restriction that groups be approximately equal in size. The data for 11 Ss were dropped from consideration, the Ss having failed to come within ± 3 standard deviations of their group average. The n per group at the completion of the study was 20, 18, 18, 18, and 17 for Groups 1 through 5, respectively.

There were verbal instructions and a demonstration of the tracking task followed by five trials during Session 1. During each of the remaining eight sessions S received 10 trials administered in five-trial blocks. There was 50 sec. rest between trials within a block and 2 min. rest between blocks. Each trial was of 70-sec. duration and performance was scored over the last 60 sec. of each trial. This avoided scoring the initial transients of tracking. Appropriate instructions were given to the experimental groups in the session during which transfer to the three- and to the two-display conditions occurred.

Integrated absolute system error served as the performance metric. This score was recorded in its original voltage units and later transformed to units of linear extent, the scale being that used on the ε display. Thus, the metric, average error, represents the average deviations of S's error amplitude distribution expressed in inches of the display scale. For purposes of analysis, the two average error scores (one for heading, the other for altitude error) were summed for each S. Thus, total system error was used to compare groups.

Results

Figure 2 provides a summary of total average error for Groups 1, 2, and 3, while Figure 3 represents the data for Groups 1, 4, and 5. Discontinuities in the functions for the experimental groups indicate the points of transfer from the five- to the three-display conditions and from the three- to the two-display conditions.

Several points are of interest in regard to these data. First, it is apparent that despite the fact that all four experimental groups experienced the

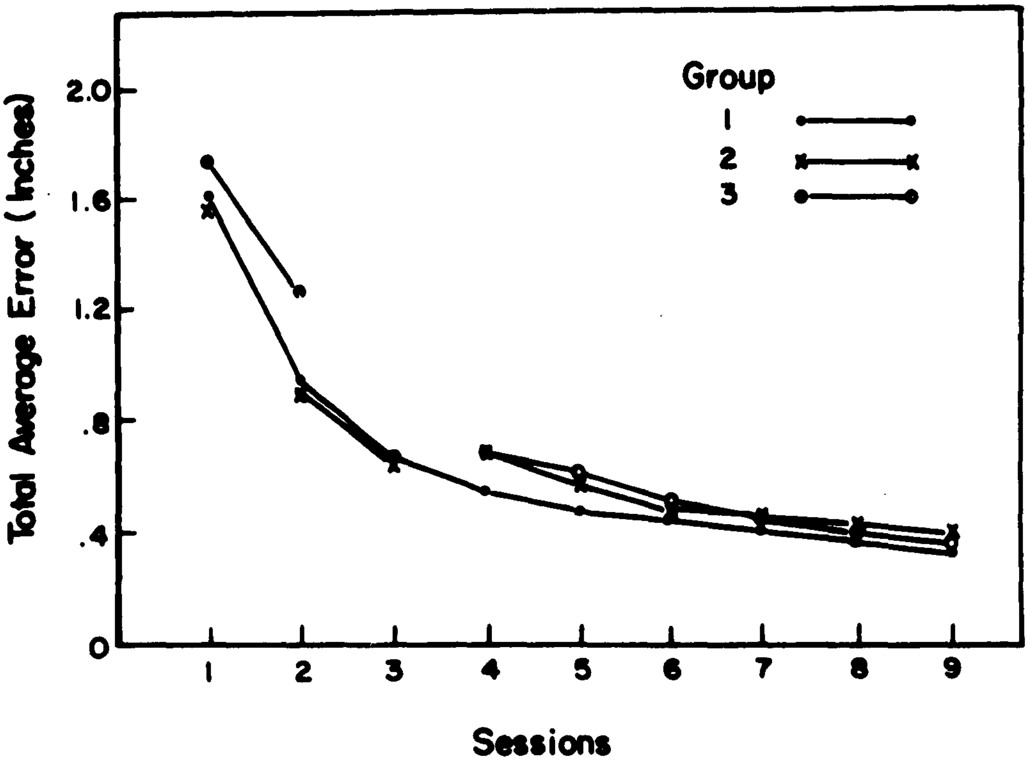

Figure 2. Training and Transfer Functions for Groups 1, 2, and 3.

same (five-display) condition in Session 1, Groups 2 and 5 appear to be superior to Groups 3 and 4. However, this apparent superiority is not statistically significant ($\underline{P} > .05$). Second, the control group (Group 1) was equal or numerically (but not statistically) superior to the experimental groups throughout the training sessions. And, finally, upon transfer the experimental groups rather obviously deteriorated in performance compared to their own pretransfer performance and compared to the level attained by Group 1. Thus, there was no advantage, in terms of tracking accuracy, to the presence of derivative information. Individual $\underline{t}$ tests were performed with the data; only Group 3 does not significantly differ from 100% (see Table 3). This is due to two subjects in Group 3 who attained the least transfer performance index of all $\underline{S}$s in the study and who increased, thereby, the intragroup variability.

These results were unexpected. It was predicted that experimental group performance would excel that of Group 1 upon transfer to the two-display condition, and it was expected that Groups 2-5 most certainly would be superior to Group 1 during those sessions wherein the former groups experienced the five- and three-display conditions. An explication of these results is weakened by virtue of the a posteriori character of such an attempt, but the following speculation may account for the unexpected results: it is probable that the advantages to control accuracy which were provided by the derivative displays were counterbalanced (or

Table 3

Analyses of Transfer Indices for Statistical Significance

Group	Transfer Index	t	df	P
2	85.8%	2.06	17	$.025 < P < .05$
3	84.2%	1.23	17	$.10 < P < .15$
4	85.5%	2.19	17	$.01 < P < .025$
5	91.9%	1.74	16	$P = .05$

overbalanced) by the time sharing required in the use of such information. Anyone experiencing flight control in an aircraft simulator for the first time is acutely aware of the difficulty encountered in setting up and maintaining an appropriate sequence of visual fixations of the several panel instruments. It is only after several such sessions in the simulator that an efficient schedule of time sharing is acquired. Figure 3 suggests that this was occurring in the case of Groups 4 and 5 where the performance curves appear to have crossed (Group 5, Session 2) or about to cross over (Group 4, Session 3) that of Group 1, but only after several training trials on the five-display condition. Unfortunately, transfer from the five-display condition occurred too early to permit a clear-cut superiority of Groups 4 and 5 to occur.

Summary

In summary of the above results it must be said that the particular schedules of withdrawal of information during training did not differentially influence performance on the final transfer (two-display) task. Further none of the training schedules employed provided for performance which was superior to that of the control group on the criterion task. As stated earlier on page 4, it is probable that had the criterion task (two displays) been more difficult, the negative results would not have been obtained. Further, as indicated in page 8, the time-sharing demand of the five- and of the three-display conditions were certainly greater than those of the two-display task. Therefore, the experimental groups were training under a handicap of time-sharing requirements not present to the same degree for the control group, further balancing the scale in favor of Group 1.

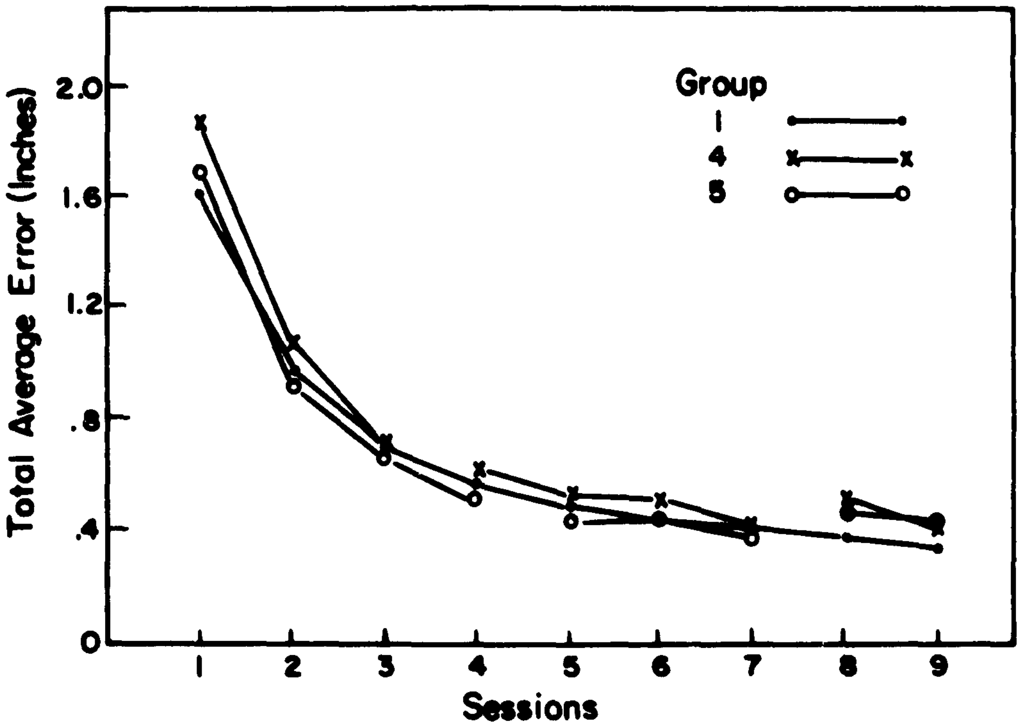

Figure 3. Training and Transfer Functions for Groups 1, 4, and 5